HEATAWARE SG Report

2026

Partners With:

Griffith University · SL2 Impact · Nusa Aksara

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Foreword

As Project Lead for HeatAware SG, I am proud to present this report as a culmination of the community-driven efforts to understand and address indoor heat exposure among Singapore's heat-vulnerable communities, especially our senior community, who have built this country from its humble beginnings.

This initiative would not have been possible without the dedication of our partners. We extend our deepest gratitude to **SL2 Impact**, whose deep community networks and facilitation enabled meaningful outreach and data collection. To the **ETHOS Project at Griffith University**, we are grateful for your generous collaboration with us and for sharing your scientific expertise, past deployment experiences, and equipment. We also thank **PT Nusa Aksara Teknologi** for their expertise in IoT development and software integration, adapting the borrowed system to Singapore's local context.

HeatAware SG is an initiative of Sustainable Living Lab (SL2), an ecosystem of organisations that design and implement solutions to navigate climate, societal, and digital transitions. Active across Asia, the US, and beyond, we combine foresight, technology, and grassroots engagement to turn complex challenges into real-world outcomes where sustainability can be lived out.

This report represents not just data, but the trust of the 201 participants who shared their experiences and the 54 households who opened their homes to us. It is our hope that these findings serve as a foundation for meaningful action.

Russell Fock
Project Lead, HeatAware SG

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Executive Summary

Singapore faces the dual threats of a warming climate and an ageing population: annual mean temperatures could rise by up to 5°C by 2100, while citizens aged 65 and above made up 20.7% of the population in 2025, up from 13.1% in 2015, and are projected to reach one in four by 2030. With age, the body's ability to regulate temperature declines, directly increasing the number of individuals vulnerable to heat-related illness. Prolonged heat exposure can lead to cramps, exhaustion, and in extreme cases, heat stroke, syncope (fainting), and edema (swelling). Hence, this convergence directly increases the number of individuals vulnerable to heat events.

HeatAware SG

Singapore's first community initiative is designed to help seniors aged 50 and above become more aware of indoor heat and better equipped to protect themselves. Between August 2025 and February 2026, there were two concurrent conducts:

Conduct 1: Heat Awareness Surveys (n=201)

112 respondents (~56%) had never heard of a heatwave, while 141 (70%) expressed concern about heat impacting their health. Residents feel the effects of heat without the awareness or vocabulary to recognise and respond to it effectively.

Conduct 2: Sensor Deployment (54 households, 646,300 readings)

Indoor temperatures were compared against the National Environment Agency (NEA) Changi Station outdoor mean of 27.4°C for the deployment period. 79.3% of all readings were at or above this outdoor reference, and 91% of households averaged warmer indoors than outdoors. The gap was most pronounced overnight: while outdoor air fell to approximately 24.4°C, indoor temperatures averaged 28.1°C, nearly 4°C warmer, at the hours when residents most rely on cooler conditions for rest.

Through this community initiative, there is a clear mandate: Seniors are unaware of the risks heat (and heatwaves) may pose to them, and are also concerned about the increasing heat they feel. As such, there is an urgent need to scale community-based heat literacy. The data suggests that indoor heat is the norm, not an exception, with 91% of homes averaging warmer indoors temperatures, validating the expansion of real-time alert systems to prioritise households with the most persistent exposure. Crucially, the readings prove that granular, in-home monitoring is not only feasible but essential, revealing exposure patterns that national weather data is unable to show. HeatAware SG has established a baseline understanding, validated the methodology, and built the community trust necessary for impact. The data no longer asks if indoor heat is a problem, but how quickly and at what scale Singapore will act to protect those most vulnerable.

Introduction

The Impending Dual Threat of Heat & Age

Singapore's Meteorological Service Singapore (MSS) declared 2024 as the country's warmest year on record, tied with 2019 and 2016, with an annual average temperature of 28.4°C. (National Environment Agency, 2025). The warming trend continued in 2025, which ranked as the eighth-hottest year on record despite the cooling influence of La Niña (Qing, 2026). That year saw the hottest June and November on record, along with 29 days of high heat stress, up from 21 in 2024 (Qing, 2026). According to Singapore's Third National Climate Change Study (V3) by the Centre for Climate Research Singapore (CCRS), annual mean temperatures could rise by up to 5°C by 2100, with daily maximum temperatures potentially increasing by up to 5.3°C (Centre for Climate Research Singapore, 2024). Furthermore, Singapore's Department of Statistics indicates that Singapore's total population grew by 1.2% in 2025; the proportion of citizens aged 65 and above has already reached 20.7%, up from 13.1% in 2015, and is projected to reach 1 in 4 citizens by 2030 (Singapore's Department of Statistics, 2025). Singapore's population is ageing while climate is warming, a convergence that directly increases the number of people vulnerable to heat events.

The human body can adapt to various climates and environments, though there are well-defined limits on how much heat an individual can tolerate, which will decline with age and illness (Kovats & Hajat, 2007). Coupled with increased exposure to hot and extreme weather events, this would also reduce individuals' psychological well-being by reducing the amount of physical activity they engage in (Zhang et al., 2023). Seniors who lack heat awareness may be even more sensitive to hot weather, making them more susceptible to the adverse mental effects of heat (Guo et al., 2025). As we age, our body’s ability to maintain thermoregulatory control and physiological adaptability will decline, making our senior population more vulnerable to heat-related illness (Awad et al., 2025).

A National Effort

In response, Singapore currently employs a comprehensive, multi-agency strategy to combat urban heat by blending infrastructure, building design, and public health policy. Key initiatives include the HDB Green Towns Programme, which retrofits blocks with cool roofs and vertical gardens (Housing & Development Board, 2025); mandatory Green Mark Certification for new public-sector buildings (Singapore Green Building Council, 2021); and a National Heat Stress Advisory that provides public health guidelines (Meteorological Service Singapore, 2023). Research institutions such as the NUS Urban Climate Lab are also critical to assessing the Urban Heat Island effect (NUS Urban Climate Lab, 2024), with initiatives like the Digital Urban Climate Twin (DUCT) simulating future scenarios to inform policy (Begum, 2024). These efforts are further strengthened by Singapore’s decision to establish a dedicated national “Heat Resilience Office” as part of its expanding climate adaptation strategy (Begum, 2026). However, despite these national-level efforts, a critical gap remains: the absence of a household-level early warning system for heat risks.

HeatAware SG

HeatAware SG is a community initiative that aims to address this gap by being the first to measure indoor heat risks directly and provide real-time alerts and protection for a key vulnerable group: seniors aged 50 and above living in Singapore's public Housing Development Board (HDB) flats. This is done by getting a baseline understanding of public heat-awareness knowledge and collecting data on indoor temperature and humidity levels in HDB flats occupied by seniors. At the national level, the initiative supports the Singapore Green Plan 2030 and the UN SDGs 3 (Good Health & Wellbeing), 10 (Reduced Inequalities), 11 (Sustainable Communities), and 13 (Climate Action).

Objectives

Enhance **heat risk awareness** among vulnerable communities through participatory data collection.

Empower vulnerable residents with **real-time, personalised heat alerts and actionable self-cooling guidance.**

Generate **granular household-level heat data** to inform broader climate resilience and urban cooling strategies.

Intended Outcomes

Increased adoption of user-friendly, low-cost self-cooling behaviours.

Improved understanding of personal heat-health vulnerabilities among senior participants.

Reduced incidence of preventable heat-related health risks among participating households.

Support urban heat island (UHI) research for climate-resilient urban planning.

Drive lasting reductions in household energy use and carbon emissions.

From August 2025 to February 2026, HeatAware SG operated in two concurrent parts:

- Conduct heat awareness surveys and offer heat-health advice via leaflets and quizzes to gather critical data and improve heat-risk awareness among Singapore's senior population;
- Deploy temperature and humidity sensors in seniors' HDB homes to monitor real-time indoor temperature and humidity levels, and send alerts with personalised cooling guidance when heat levels become potentially unsafe.

Conduct 1: Heat Awareness Surveys

To gain a better understanding of our senior population's perception of heat, a survey was conducted between November 2025 and January 2026 to assess general heat awareness and the most common cooling strategies used (*Appendix 1*).

Working with our outreach partner, SL2 Impact, which runs the largest repair movement in Singapore: Repair Kopitiam, these surveys were conducted at multiple locations across the country during their monthly community repair meetups (Figures 1 & 2).

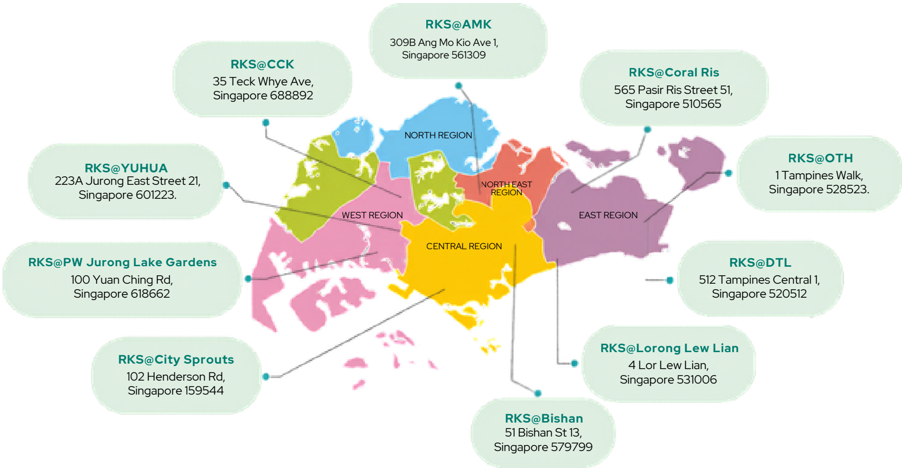


Figure 1: Repair Kopitiam's 10 monthly community repair meetup locations

A total of 201 responses were collected, primarily targeting seniors in HDB households. Of these, 187 respondents were aged 50 and above, with 170 residing in HDB flats (including 1-room, 2-room, 3-room, 4-room, and 5-room/Executive units).

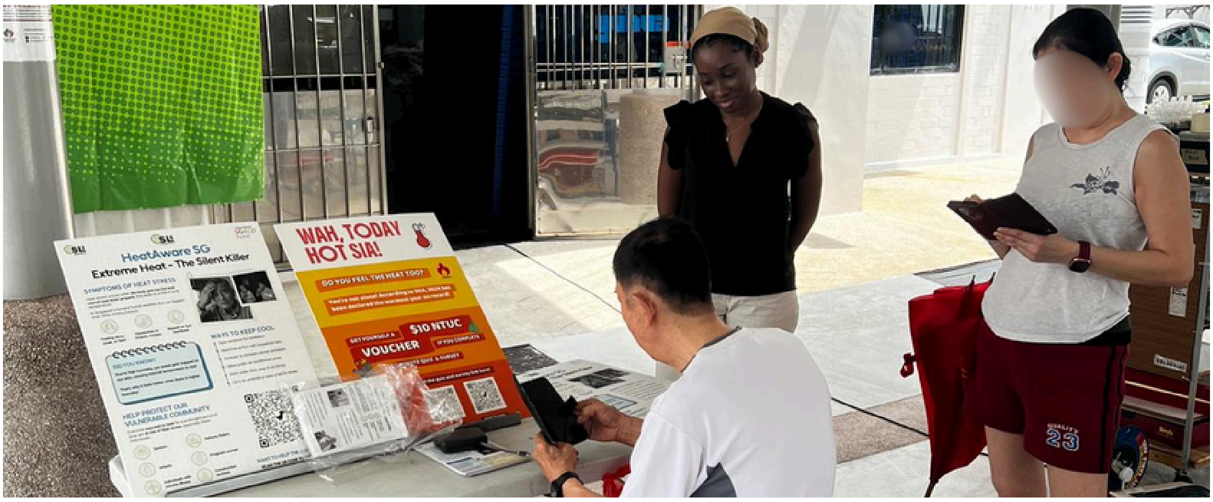


Figure 2: One of several community engagements to collect survey responses

Findings from Conduct 1

Data from the respondents revealed critical insights into the heat experiences of senior residents in Singapore:

- **A critical awareness gap exists:** Across all 201 respondents, 112 (~56%) have never heard of a heatwave, and 100% are not aware of the definition. This lack of awareness is even more pronounced among those experiencing discomfort, where of the 70 respondents who indicated their homes are "uncomfortable" or "very uncomfortable" on hot days, 50 (~71%) have never heard of a heatwave. This reveals that while residents feel the heat, they lack the vocabulary and risk awareness to recognise dangerous heat events, leaving them vulnerable and unprepared.

- **Natural ventilation is insufficient during peak heat:** Among the 70 respondents who are "uncomfortable" or "very uncomfortable", 59 (~84%) keep windows open most of the day, yet still suffer from heat. This suggests that relying on airflow alone is insufficient during extreme heat periods, and that residents may be exposing themselves to hot outdoor air without realising it. It also suggests that passive cooling behaviours may be insufficient and other low-cost, affordable cooling solutions are required.

- **Low Air Conditioning (AC) usage correlates with discomfort:** Of the 174 respondents reporting any level of heat discomfort, 86 (~49%) use their air conditioning “never”, “occasionally” or “rarely”. Despite most HDB flats now being fitted with AC units, this pattern may stem from a combination of factors: behavioural habits, a cost-saving mentality, environmental awareness, or cultural beliefs around health and acclimatisation. Regardless of the underlying reasons, the infrequent use of AC leaves residents exposed to potentially dangerous indoor temperatures. This underscores the urgent need for sustainable cooling innovations that are affordable, culturally acceptable and do not rely solely on active mechanical systems.

- **Passive cooling measures are underutilised:** Only 70 (roughly 35 per cent) of 201 respondents use curtains or window shades to block heat. This suggests a significant gap in awareness regarding preventive cooling strategies. Rather than mitigating solar gain before it enters the home, residents, particularly seniors, tend to rely on reactive cooling methods such as air conditioning, fans and cool showers. This highlights a critical opportunity for education: many residents may not realise that simple, low-cost modifications to their environment can be just as effective as mechanical cooling in maintaining a safe indoor temperature.

- **Housing orientation influences thermal comfort:** Among 70 respondents who are uncomfortable on hot days (61 "uncomfortable" and 9 "very uncomfortable"), North-facing (18 respondents, 26%) and West-facing (15 respondents, 21%) homes are the most affected. However, West-facing homes experience more heat, making up 21% of uncomfortable respondents but 33% of the "very uncomfortable" category, due to harsh afternoon sun. In contrast, North-facing homes face discomfort from indirect sunlight and less wind during certain seasons. These findings suggest that both orientations may require targeted retrofits, such as solar films or external shading, to address increased afternoon heat.

- **Health concerns are high despite limited action:** Across all 201 respondents, 141 (70%) are “very concerned” or “somewhat concerned” about heat impacting their health. Despite recognising heat as a health threat, most seniors are not taking adequate action, possibly due to cost, lack of awareness, or misconceptions about what measures may help to cool their homes.

Limitations of the Survey

Several limitations should be noted:

- **Window orientation uncertainty:** Many participants were unsure of their home’s window orientation, making it difficult to draw precise conclusions about directional heat exposure.

- **Subjective thermal comfort:** Individual perceptions of thermal comfort vary widely, presenting a challenge for objective analysis.

- **Unquantified home clutter:** Factors such as home clutter may influence heat retention but are difficult to quantify objectively.

- **Skewed housing sample:** The sample was skewed toward residents of larger HDB flats, with 166 of 201 respondents (83%) living in 3-room, 4-room, or 5-room/Executive units. As a result, seniors in smaller 1- and 2-room flats, especially rental units, were underrepresented, and the findings may not fully reflect the experiences of those in more vulnerable housing situations.

Conduct 2: Heat Monitoring Systems Deployment

To gain a real-time understanding of indoor heat exposure, temperature and humidity data were collected using Internet of Things (IoT) sensors developed by the ETHOS Project at Griffith University. These were borrowed and reprogrammed for localised use. These sensors were deployed island-wide from November 2025 to February 2026 across 54 voluntary HDB households (Figure 3) with occupants aged 50 and above, drawn from the 201 survey respondents, to ensure the data collected reflected the experiences of Singapore's senior population.

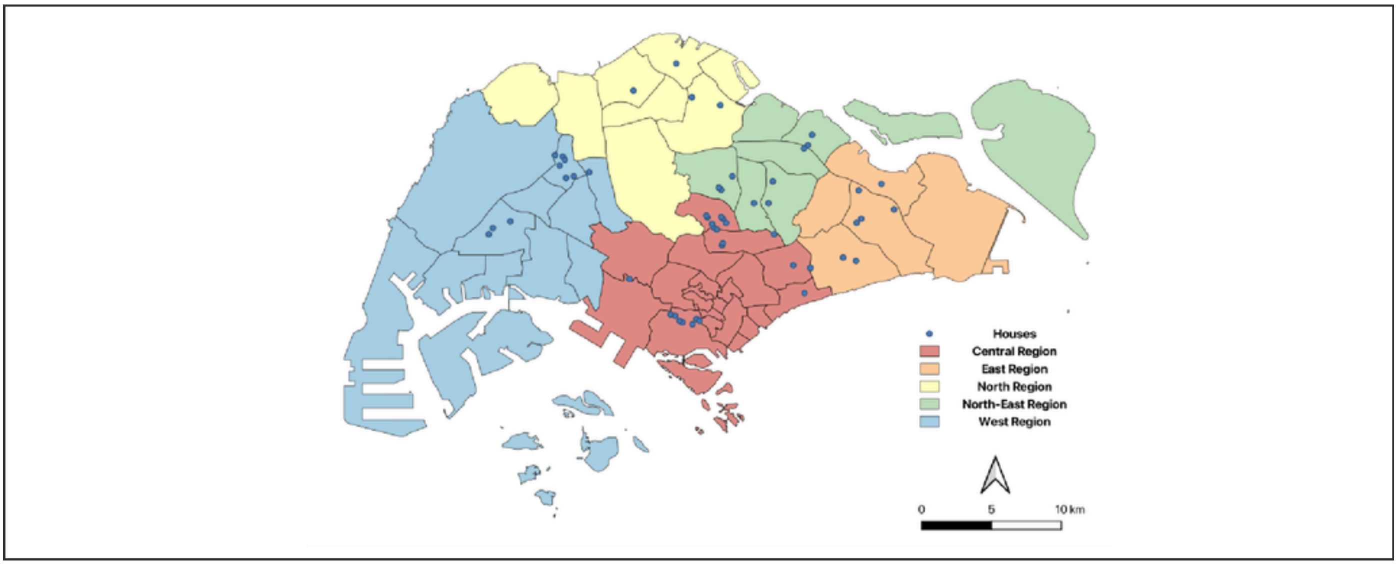


Figure 3: Location of the 54 HDB houses where the sensors were deployed

Each household had one base station and three sensors (*Appendix 2*) installed for 30 days to monitor temperature and humidity in at least three areas in the household (living room, kitchen, main bedroom, guest bedroom, study and dining room). The system is capable of holding up to four sensors and was designed to send alerts with personalised cooling guidance when indoor heat levels became potentially unsafe (*Appendix 3*). Further information about the system's design and thermal model may be found in the ETHOS Project's publication (Oberai et al., 2025).

Outdoor Temperature Reference

To understand how indoor temperatures in senior HDB households relate to the outdoor climate, this report compares sensor readings from 54 homes against the mean outdoor temperature recorded at Singapore's Changi climate station over the same period. While four other climate stations also exist (Paya Lebar, Seletar, Sembawang, and Tengah) and have long-term records, only Changi had monthly mean data available for the data collection window, making it the most suitable benchmark (Meteorological Service Singapore, 2026).

The resulting outdoor mean of 27.4°C serves as a locally grounded reference point. It is used only to show how indoor conditions reflect the ambient heat from the period, and is not intended to assess medical risk, imply safety thresholds, or make any claims about health outcomes.

Data at a Glance

Metric	Value	Notes
Total households monitored	54	Deployed across Singapore (Figure 3)
Total number of sensors deployed	162	3 sensors per household
Total individual readings	646,300	10-minute intervals throughout a 30-day deployment period
Deployment period	Nov 2025 – Feb 2026	Monsoon / inter-monsoon season
Outdoor Temperature Reference	27.4°C	NEA's Changi Station mean during the deployment period
Overall indoor mean temperature	28.33°C	Median: 28.37°C
Overall indoor mean Relative Humidity (RH)	73.80%	Median: 74.4% Range 31.6–95.3%
Overall mean Heat Index (Temp & Humidity)	32.02°C	~5.4°C above mean indoor temp

Table 1: Dataset Summary

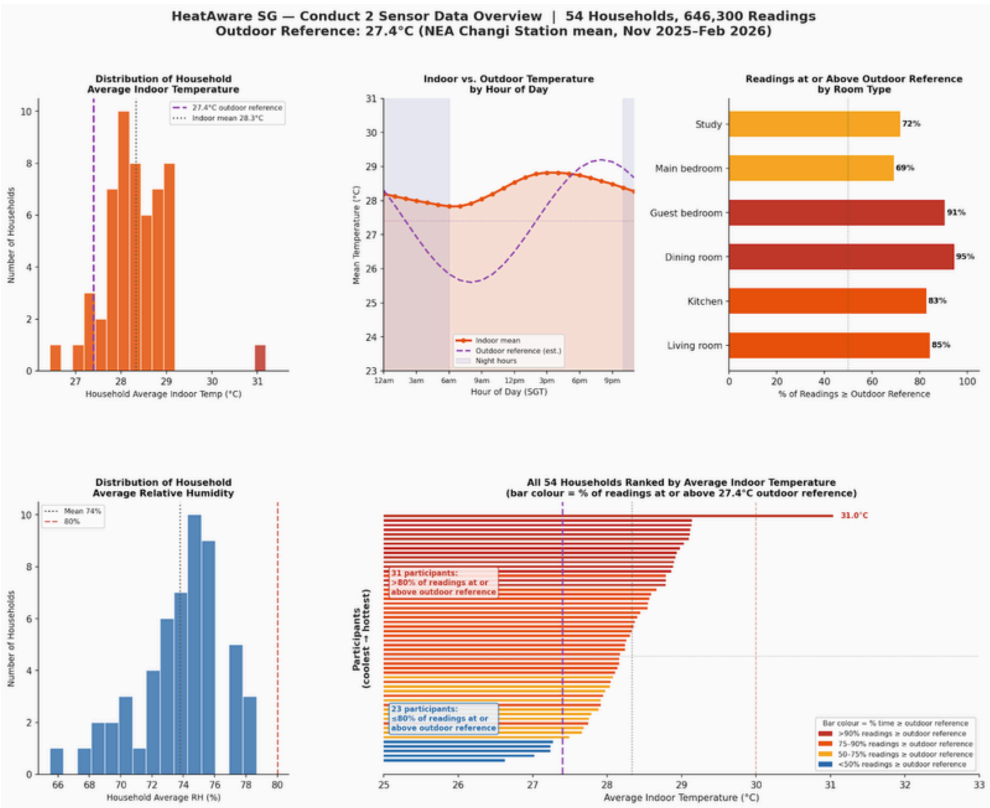


Figure 4: Top: Household temperature distribution; diurnal curve (all homes); % readings ≥28°C by room type. Below: RH distribution; all 54 households ranked by average indoor temperature.

Time of Day	Indoor Mean	Outdoor Reference	Temperature Difference
Peak afternoon (around 3pm)	28.82°C	31.0°C	Indoor ~2°C cooler
Daytime (9am – 6pm)	28.56°C	29°C	Comparable
Early evening (6pm – 10pm)	28.62°C	27°C	Indoor ~1.6°C warmer
Night (10pm – 6am)	28.11°C	~24.4°C	Indoor ~3.7°C warmer
Coolest indoor hour (6am)	27.83°C	24.4°C	Indoor ~3.4°C warmer
Average diurnal swing	0.99°C	6–7°C	Indoor varies far less than outdoor across the day

Table 2: Indoor vs. Outdoor average temperatures

Findings from Conduct 2

Data from the sensor deployment across 54 households revealed critical insights into the actual indoor heat exposure experienced by senior residents in Singapore:

- **Homes retain heat rather than cool them:** 79.3% of indoor temperature readings are at or above the outdoor mean, with 49 (91%) households averaging warmer than outdoor conditions. Rather than acting as thermal shelters, homes are absorbing and retaining heat, resulting in indoor environments that often mirror or exceed outdoor ambient conditions. This indicates that being indoors does not necessarily reduce exposure to heat, and that residential environments themselves can become sustained sources of thermal stress.

- **Indoor heat persists overnight:** Indoor temperatures show minimal day–night variation (~1°C), remaining elevated even as outdoor temperatures drop significantly. Overnight, indoor conditions average ~3.7°C warmer than outdoor air (Table 2), with 73.7% of readings still above the outdoor mean. This means in the event of a heatwave, residents may experience prolonged, uninterrupted exposure to heat, impacting sleep, limiting the body's ability to recover, and increasing the risk of cumulative heat stress, particularly among elderly populations.

- **Heat exposure varies significantly across homes:** Intensity of exposure varies significantly, with 31 (57%) households exceeding outdoor temperatures more than 80% of the time, while 15 (28%) households exceed this threshold more than 90% of the time. This suggests that while heat exposure is a systemic issue, certain households face disproportionately higher risk due to factors such as housing characteristics, ventilation, and behaviour, making targeted interventions critical.

- **Humidity amplifies perceived heat stress:** With average indoor humidity at 73.8%, the mean Heat Index (temperature & humidity) reached 32.02°C, over 5°C higher than the measured air temperature. This demonstrates that temperature alone does not fully capture indoor thermal conditions, as high humidity significantly increases perceived heat and physiological strain. As a result, many households may be experiencing higher levels of heat stress than air temperature readings alone would suggest, reinforcing the importance of incorporating humidity into monitoring and overall heat risk evaluation.

Limitations of the Deployment

- **Temperature-only analysis:** Currently, this report focuses on air temperature to maintain direct alignment with Changi climate station records. However, acknowledging that air temperature alone may understate physiological strain in Singapore's tropical climate, we are incorporating Heat Index analysis to better quantify the "real-feel" health risks and provide a more nuanced understanding of human thermal comfort.

- **Outdoor reference may not reflect localised conditions:** Indoor temperatures are benchmarked against a single NEA Changi reference (27.4°C), which may not fully capture microclimate differences across neighbourhoods. As a result, the indoor–outdoor comparison may not precisely reflect local conditions for every household.

- **Short testing period:** The data collection was conducted for a period of 30 days across the November to February period, rather than a year-long period. Hence, although the period saw above-average temperature readings, including the warmest November on record, this meant the results are difficult to infer that there were any significantly elevated heat conditions and may not fully reflect year-round indoor environments.

- **Sensor data does not capture behavioural context:** While the dataset provides continuous environmental measurements, it does not account for the participant's time-specific behaviour in the 30 days (e.g., air-conditioning use, window opening, time spent in rooms). As such, it reflects ambient conditions rather than individual exposure and/or coping actions.

- **Other compounding environmental factors:** Although humidity is measured, temperature remains the primary basis for comparison. As shown in the dataset, high humidity significantly increases perceived heat, meaning temperature alone may underestimate actual thermal stress. Air flow/wind speed was also a factor not measured during this data collection phase.

- **Outliers and activity-driven spikes influence extremes:** Three households exhibit extreme or atypical readings, including persistently high indoor temperatures and short-term spikes (e.g., during cooking or potential technical sensitivity issues). While these are valid observations, they may not represent typical household conditions and should be interpreted as specific cases rather than cohort-wide norms.

- **Small-scale limits generalisability:** The data collection covered only 54 senior households within selected HDB areas, providing a limited dataset but not a fully representative sample of all HDB housing types or vulnerable populations in Singapore.

Data availability

The data used and/or analysed for this report are available from the corresponding author upon request. The data are not publicly available due to privacy or ethical restrictions.

HeatAware SG Recommendations

- **Expand heat risk framing to include indoor environments:** Heat management strategies should move beyond an outdoor focus to recognise that indoor spaces can sustain equal or higher heat exposure over prolonged periods. Public communication and policy approaches should explicitly incorporate indoor residential environments, particularly for seniors who spend most of their time at home.

- **Promote personalised, context-specific cooling interventions:** Heat exposure and vulnerability vary significantly across households, even within similar housing types. Rather than generic advice, future approaches should adopt a personalised model that assesses each household's specific exposure patterns, living conditions, and risk profile to deliver simple, low-cost, and actionable cooling strategies, including optimising ventilation, improving passive shading, using fans effectively, and managing indoor heat sources tailored to their unique home environment.

- **Prioritise high-exposure households for targeted support:** While elevated indoor temperatures are widespread, a subset of households experiences consistently higher and more persistent heat exposure, including overnight. These households should be identified and prioritised for deeper assessment and targeted interventions, ensuring resources are directed where they are most needed.

- **Scale household-level monitoring as a foundation for action:** The data demonstrates that continuous, in-home monitoring is both feasible and valuable, revealing exposure patterns not captured by national weather data. Scaling this approach would support more precise identification of vulnerable households, enable targeted interventions, and strengthen evidence-based decision-making.

- **Target deployment in high-risk periods and neighbourhoods, for longer:** Future phases should prioritise monitoring and intervention in warmer periods of the year and neighbourhoods more exposed to heat, where indoor conditions are likely to be most elevated. Focusing on these high-risk temporal and geographic hotspots will improve the efficiency of deployment, enable more targeted support, and generate deeper insights into how heat exposure varies across different urban contexts.

Appendix 1: Heat Awareness Survey Overview

The survey was conducted on Google Forms and structured across four main sections to capture demographic background, housing characteristics, heat knowledge, and cooling behaviours.

Section 1: Respondent Profile

- Full name, age, gender
- Contact details (mobile number, full address, postal code)
- Languages spoken, race/ethnic group
- Employment status, education level
- CHAS card status

Section 2: Housing Environment

- HDB housing type, floorspace, unit orientation
- Air conditioner presence, location, and usage frequency
- Window opening habits
- Primary daytime room
- Mobility challenges and home accessibility
- Household composition and size
- Clutter levels (inside home, outside home, neighbour's unit)
- Lift access
- Additional observations about home environment

Section 3 & 4: Heat Knowledge & Cooling Behaviours

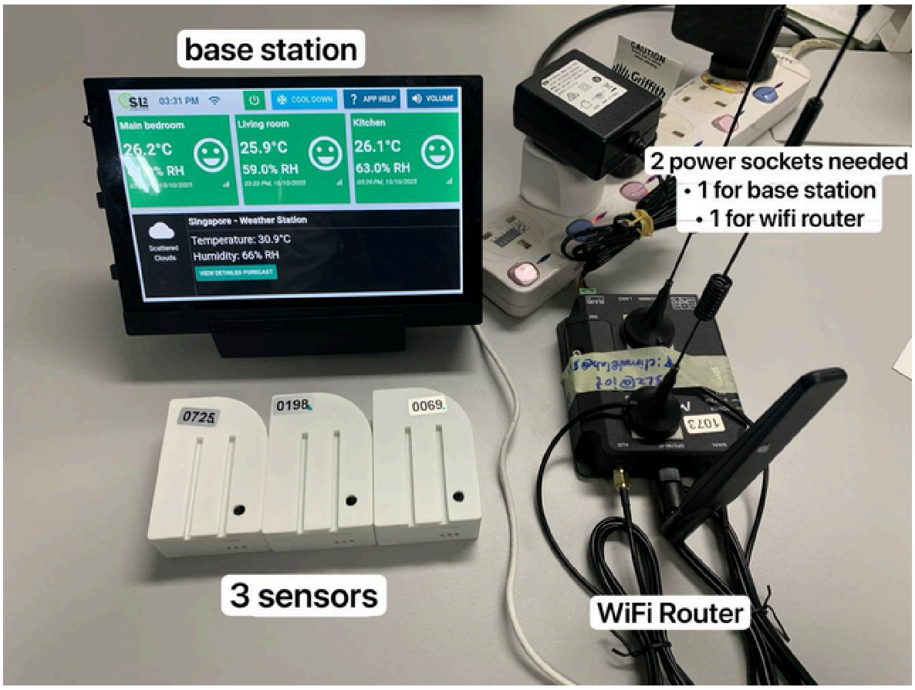
- Awareness of heatwaves (prior knowledge and definition)
- Perception of heatwave frequency in Singapore
- Level of concern about heat impacting health
- Experienced heat-related symptoms (e.g., dizziness, fatigue, difficulty sleeping)
- Self-reported home comfort level on hot days
- Current cooling methods used (e.g., air conditioning, fans, curtains, cool showers)
- Behavioural changes during periods of extreme heat
- Reasons for not altering cooling behaviours (if applicable)

Section 5: Data Protection Consent

- Acknowledgement of Personal Data Protection Act (PDPA) compliance
- Consent for data collection, use, and disclosure for the HeatAware SG initiative

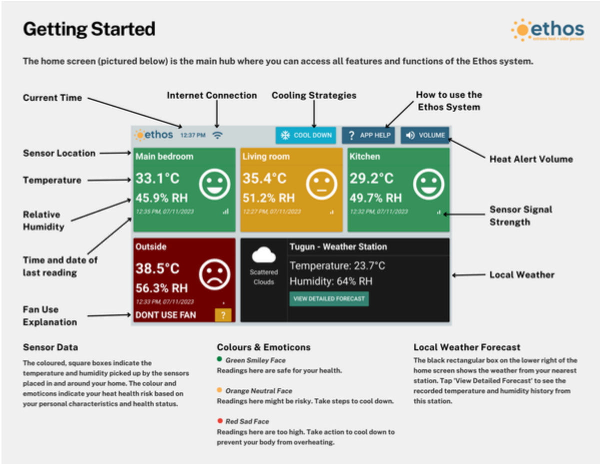
Appendix 2: HeatAware SG Deployment Equipment

Household set up with a WiFi Router



Household set up without a WiFi Router

Appendix 3: The Ethos System



Cooling Strategies Available In The ETHOS System:

1. Direct Body Cooling (High impact)

- Cold bath
- Cold shower
- Ice pack application
- Hand/forearm immersion bath
- Foot bath
- Self-dousing (wetting skin/clothing)

2. Environmental Cooling

- Air conditioning
- Using a fan
- Opening/closing windows, blinds, curtains (ventilation & shading control)

3. Physiological / Behavioural Cooling

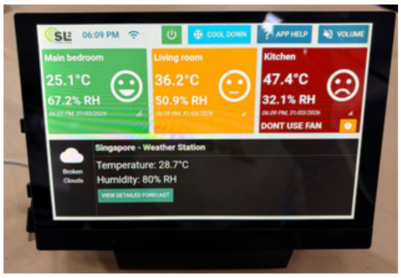
- Sitting down quietly (reducing metabolic heat)
- Drinking cool water (hydration)

4. Clothing-Based Cooling

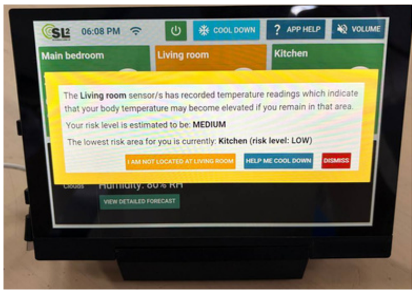
- Removing excess clothing
- Dampening clothing (wet towels, wet garments)

Quick Insight (from effectiveness rankings)

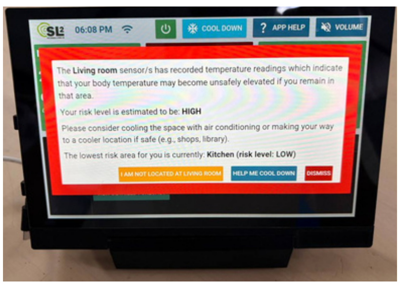
- Most effective: Cold bath, air conditioning
- Moderate: Cold shower, sitting quietly, fans
- Lower but accessible: Hydration, clothing adjustments, window management



Appendix Figure 3.1: The 3 possible sensor reading colours on the ETHOS System



Appendix Figure 3.2: Yellow/Orange reading pop up alert



Appendix Figure 3.3: Red reading pop up alert

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